SPECTRAL ANALYSIS AND PHYSICAL PROPERTIES OF MAIN-SEQUENCE STARS*

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Abstract

The analysis of stellar spectrum was considered as an efficient tool for studying the chemical composition of stars and measuring the physical properties. In this paper, we selected four stars of the main- sequence band namely (HD 6111, HD 221741, SU Aur, HD 5351) for analyzing their spectra. The chemical composition of each star can be extrapolated from their own absorption spectrum by comparing their positions in the spectrum with those observed from pure source in the laboratory, while from the emission spectra, we measured the physical properties including, temperature, mass, radius, velocity, and lifetime. The results indicated that the selected stars of the main sequence have the chemical composition hydrogen, ionized helium, Fe, C, Si, . Our calculations of the stars under investigation give rise to the following physical properties, their surface temperature between (4983 – 8130K), mass between (0.74 – 2 M_s), radius between (0.795 - 1.77 R_s), luminosities between (0.35 - 10) and lifetime between (2 – 20 Gy).

الخلاصة

تحليل الطيف النجمي هو وسيلة كفؤة لدراسة التركيبة الكيمائية للنجوم وقياس الخواص لفيزيائية لها. في هذا البحث تم اختيار اربعة نجوم من نجوم التتابع الرئيسي لتحليل طيفها وهي: (HD 6111, HD 221741, SU Aur, HD 5351) لقد تم استخدم طيف الامتصاص لتحديد التركيبة الكيمائية لكل نجم من خلال مطابقة خط الامتصاص مع العناصر الكيمائية المتعددة او المركبات الجزيئية وذلك بمقارنة مواقعها المقاسة بواسطة المصدر الرئيسي في المختبر, ومن طيف الانبعاث تم قياس الخواص الفيزيائية المتضمنة درجة الحرارة , الكتلة,أنصاف الأقطار,السرعة, وعمر النجم.أظهرت نتائج التحليل ان معظم نجوم التتابع لرئيسي التي هي قيد البحث لها التركيبة الكيمائية هيدروجين,ايون الهليوم,كاربون , حديد,سليكون وتمتلك الخواص الفيزيائية والتي تتراوح درجة الحرارة بين (4983 – 8130K) وكتلته بين (0.74 – 2 M_s) ونصف قطر بين (0.795 - 1.77 R_s) ونورانية(10 – 0.35) وعمر يتراوح بين (2 – 20 Gy).

Introduction

Astronomers used stellar spectrum to obtain a tremendous amount of information about stars, including temperature, chemical compositions, and the speeds with which they approach or recede from us. They can search for the atoms" signature" by measuring how much light is present at each wavelength [1]. In 1979, Castell and Hvala [2] studied the spectral variability of the (Si) of the (HD 224801). Luck and Bond [3] analyzed high- dispersion Mount Wilson spectroscopic data and obtained atmospheric parameters and chemical abundances for (26) distant super giants of spectral types (G) through (M). Smith and Dworetsky [4] studied the abundance of five iron-peak elements in a sample of forty normally, superficially normal, and Hg Mn-type late-B stars are derived by spectrum- synthesis analysis of co-added high- resolution (IUE) spectra. A large part of the effort in automating stellar spectral classification has focused on automating the MK system, and most of this effort has concentrated on the application of supervised feed-forward neural networks. In (1999), Smith, H., [5] studied density chemical

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composition and physical properties of spectral types (O, B, A, F, G, K, M, L). The stellar spectra are very useful technique to collect information about the stars like chemical composition of the outer part of a star and the physical properties of it. In the present work, four stars have been selected from main sequence band to study and analyze their spectra in order to determine the chemical elements abundance and measuring the physical properties as shown in the next sections.

Experimental Data

Our study concentrated on four stars selected from main-sequence band to analyze their absorption and emission spectra. All the observation of the stars ((HD 6111, HD 221741, SU Aur, HD 5351),) was taken from (IUE Atlas: Valenti, Fallon, & Johns-Krull, 2003) [6].

Results and Discussion

The stellar spectrum is created by the absorption of all the different elements that make up a star. The absorption lines in the star can be identified with individual chemical elements or molecular compounds by comparing their positions in the spectrum (their wavelengths) with those observed from pure source in the laboratory. Figures (1 - 4) illustrate the absorption spectra of the selected stars (HD 6111, HD 221741, SU Aur, HD5351), respectively. For each star, we matching the wavelengths of the absorption lines in the spectrum with those observed from the pure source in the laboratory using IUA Atlas [7]. Tables (1 - 4) reflect the extrapolated chemical elements for the stars (HD 6111, HD 221741, SU Aur, HD5351), respectively. The results indicated that the pattern of absorption lines change greatly from Class "O" to Class "M" this is due to a change in the chemical composition of the star. Also, we examined the digital spectra of the selected seven unknown stars, to determine the spectral type of each star. The spectra can be compared visually with the spectra of standard stars of known spectral types (MK) which are taken from Department of physics, Gettysburg Collage, PA. (2003)(figure 5) [8].We used one or two spectral lines for making a refined classification and by looking at the relative strengths of characteristic lines, we will be able to estimate the spectral types of unknown stars. Table(5) shows the spectral type of select stars

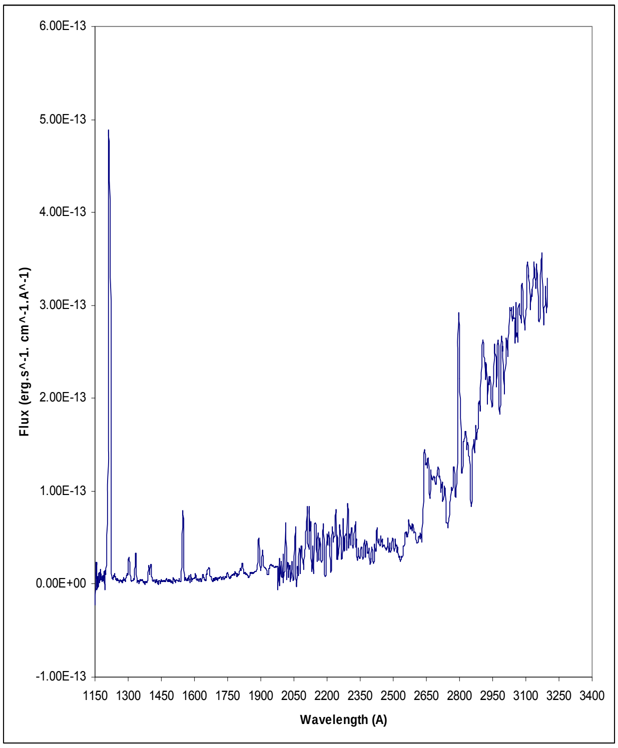


Figure (1):The Absorption Spectrum of Star (HD 6111).

Table (1): The Chemical Composition of the star (HD 6111)

Chemical Element	Wavelength (A)	Wavelength in laboratory (A)[7]
H I	1215.60	1215.668
Mn III	1648.40	1648.46
He II	1630.40	1630.40
Si IV	1790.26	1790.28
Cr I	2088.17	2088.19
Cr II	2202.99	2202.97
Cr I	2751.22	2751.19
Fe I	2799.14	2799.13

Figure (2): The Absorption spectrum of Star (HD 221741).

Table (2): The Chemical Composition of the star (HD221741)

Chemical element	Wavelengt h (A)	Wavelength in laboratory (A)[7]
Fe II	1121.61	1121.987
Pb III	1308.16	1308.10
Mo IV	1336.66	1336.696
Fe III	1549.55	1550.19
Si I	1893.2	1893.22
Cr II	2013.61	2013.65
Fe II	2109.86	2109.861

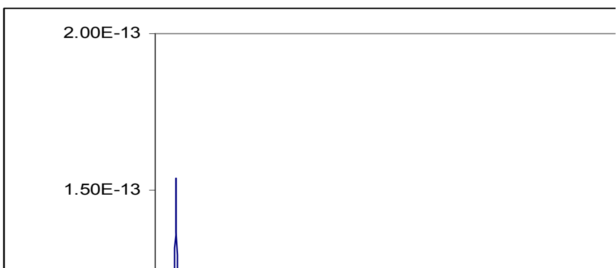


Figure (3): The Absorption spectrum of Star (SU Aur).

Table (3): The Chemical Composition of the star (SUAur)

Chemical Element	**Wavelength (A)**	**Wavelength in laboratory (A)[7]**
H I	1215.53	1215.668
O I	1306	1306.023
Si IV	1402.69	1402.73
C IV	1548.2	1548.195
He II	1640.25	1640.332-1640.474
Si II	1816.91	1816.94
Si III	1895.64	1895.64
Fe II	2321.67	2321.67
Fe II	2631	2631.045
Fe II	2711.87	2711.842
Mg II	2802.7	2802.698
Mg I	2846.71	2846.71

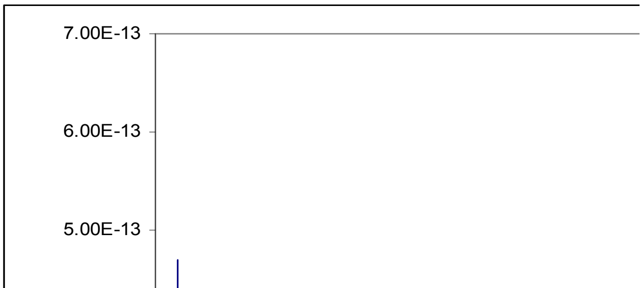
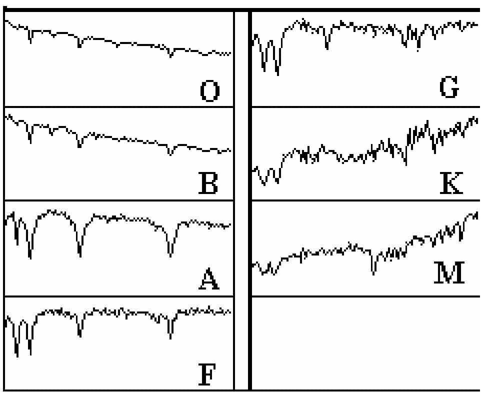


Figure (4): The Absorption spectrum of Star (HD 5351).

Table (4): The Chemical Composition of the star (HD 5351)

Chemical Element	Wavelength (A)	Wavelength in laboratory (A)[7]
H I	1215.45	1215.668
O I	1302.40	1302.174
Si IV	1393.54	1393.73
C IV	1548.170	1548.195
He II	1640.40	1640.33
Si II	1817.40	1817.42
Si III	1898.46	1898.46
V II	2114.34	2114.40
Fe II	2357	2375.005
Fe II	2406.53	2406.660
Fe II	2581.09	2581.111
Ti I	2590.29	2590.29
Fe II	2628.30	2628.291
Mg II	2797.96	2797.989
Mg I	2852.11	2852.12
Fe II	2922	2922.023



Figure(5): Digital Spectra of the Principal (MK) Types[8]

Table (5): The spectral type of select stars

Star's Name	Spectral Type
HD 6111	A
HD 221741	F
SU Aur	G
HD 5351	K

The physical properties of the stars can be determined from their spectra. Figures (6-9) illustrate the emission spectra of the mentioned stars. The wavelength of a maximum emission in each case was used to calculate the temperature as follows [9]:

$$\lambda_{\max}\ (nm) = \frac{3x10^{6}}{T\,(K)} \quad .... \quad .... \quad .1$$

From (H-R) diagram of the selected stars, the luminosities for each star can be determined .The mass, radius, velocity, and lifetime of each star were also calculated using equations (2 -5), respectively [10]:

$$\frac{L_*}{L_s} = \left[\frac{M_*}{M_s}\right]^{3.5} \quad .... \quad .... \quad ..\ 2$$

$$L = 4\pi R^{2}\sigma T^{4} \quad .... \quad .... \quad ...\ 3$$

$$t = \frac{10^{10}\ M_*}{L_*}\ years \quad .... \quad .... \quad 5$$

Where

L_*: represents the luminosity of stars

L_s: represents the luminosity of sun

M_*: represents the mass of stars

M_s: represents the mass of sun

σ: is the Stefan- Boltzmann constant

V: is the source's radial velocity and c is the speed of light. That is, the change in wavelength (Δλ) created by motion of the star (or observer) divided by the wavelength in the absence of motion is just the radial velocity of the star divided by the speed of light. The results from applying these equations were presented in table 6. Also, we compared the results with these found by Smith [11] for different spectral types.

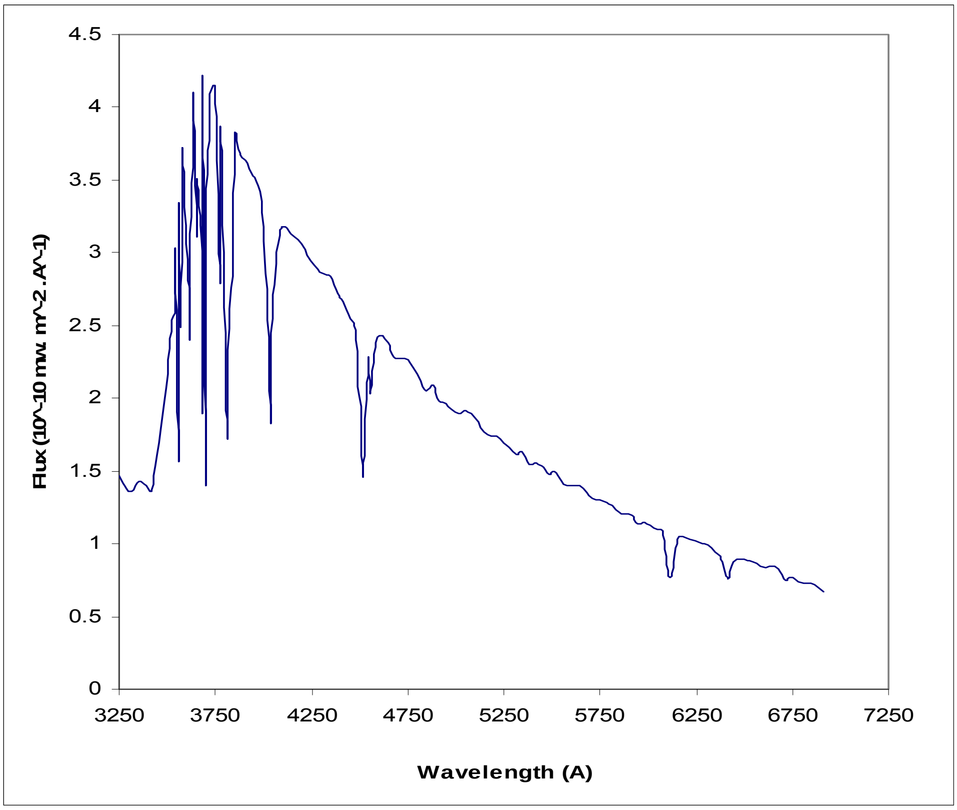


Figure (6): The Emission Spectrum of Star (HD 6111)

$$\frac{\Delta\lambda}{\lambda} = \frac{V}{c} \quad .... \quad .... \quad .... \quad 4$$

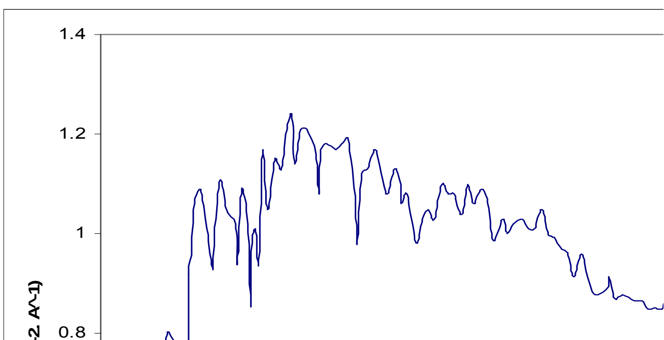


Figure (7): The Emission Spectrum of Star (HD221741)

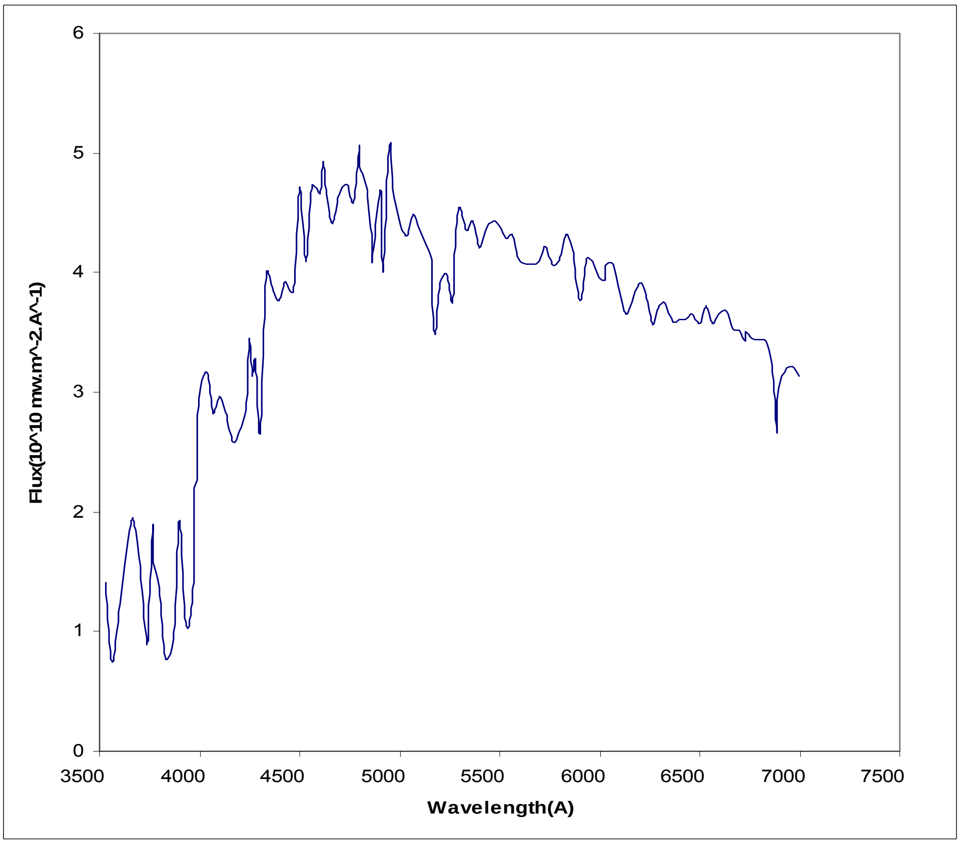


Figure (8): The Emission Spectrum of Star (SU Aur)

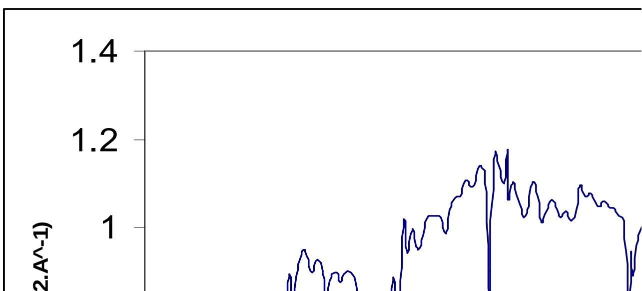


Figure (9):The Emission Spectrum of Star (HD5351)

Table (6): The physical parameters calculated for the stars under investigation

Parameters	HD 6111	Smith [11]	HD 221741	Smith [11]	SU Aur	Smith [11]	HD 5351	Smith [11]
Maximum wavelength (A)	3690		4200		4950		6020	
Temperature (K)	8130	7500-10000 K	7142.28	6000-7200 K	6060	5500-6000 K	4983	4000-5250 K
Luminosity	10 L_s	8-55 L_s	5 L_s	2.0-6.5 L_s	0.6 L_s	0.6-1.5 L_s	0.35 L_s	0.10-0.42 L_s
Radius	1.77 R_s	1.7-2.7 R_s	1.5 R_s	1.2-1.6 R_s	0.76 R_s	0.8-1.1 R_s	0.795 R_s	0.65-0.8 R_s
Mass	2 M_s	2-3 M_s	1.58 M_s	1.1-1.6 M_s	0.86 M_s	0.9-1.05 M_s	0.74 M_s	0.6-0.8 M_s
V_c (Km/sec)	-16.02		-100.8		-34.05		-1.05	
t (Gy)	2	2-440 MY	3	3-7 GY	14	8-15 GY.	20	17-20 GY

Conclusions

The following points can be concluded from this study:

1-Some absorption lines are very weak, just shallow dips in the spectrum, whereas others are completely black. The" strength" of an absorption line depends on the amount of the particular chemical element in the star causing the line and on the efficiency of absorption. The important thing to remember about absorption lines is that every atom of particular element will always have the same pattern of line all of the time.

2- The analysis of the absorption spectra showed that the selected stars of the main sequence, those fusing hydrogen in their core, have the chemical compositions, hydrogen, ionized helium, Fe, C, and Si. From measuring the physical properties of selected stars, we found that most have surface temperatures between (4983 – 8130 K), masses between about (0.74 – 2 M_s), radii between (0.795 - 1.77 R_s), luminosities between (0.35 – 10 L_s) and lifetime between (2 – 20 Gy.).

3- The lifetime of main-sequence star depend on its mass and luminosity. The massive stars have much shorter lifetimes, despite having more fuel, because they burn it so much faster to supply their greater luminosity. From the physical properties of selected stars, it could be seen that high-mass stars are both hotter and more luminous than low- mass stars, this relation between mass, temperature, and luminosity results from the condition that the gravity and pressure inside a star must be in balance. The gravitational attraction of a large mass is greater than that of a small mass, other things being equal. That greater gravitational attraction therefore requires greater pressure to offset it. Thus high-mass stars must have a higher internal pressure than low-mass stars have. A higher temperature can achieve that higher pressure, thus a higher-mass star must have a hotter core than a low-mass star has. The hotter core then leads to a higher luminosity for massive stars.

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